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2 Systems Engineering Overview

Systems Engineering is a widely accepted methodology for developing dynamic, large-scale projects, particularly those involving both technical and human components. The Concept of Operations “starts” the Systems Engineering process and is the foundation for the activities that follow. Therefore, understanding the systems engineering process is essential for proper development and use of a Concept of Operations for any application. This is especially true at the regional level, where a high-level analysis of multi-user expectations is essential to support complex high-level requirements development. This chapter provides a very brief overview of the systems engineering process (For a more detailed overview see the companion document, *Developing and Using a Concept of Operations in Transportation Management Systems Handbook*). It is for readers with a moderate amount of Systems Engineering experience who need a quick review. Those already familiar with systems engineering can skip over this chapter. For those who are not familiar with Systems Engineering, it is suggested that you consult the more in-depth reference listed at the end of this chapter (Gonzalez, Paul J. Building Quality Intelligent Transportation Systems Through Systems Engineering. Report No FHWA-OP-02-046. April 2002). This chapter will be followed by a discussion of the importance of the development and use of a Concept of Operations in applying the systems engineering process to regional integration projects in Chapter 3.

2.1 CHAPTER OVERVIEW

The material in this short chapter is an abbreviation of the description of the Systems Engineering process in the companion document and is identical to Section 2.1.2 of that document, entitled "The Systems Engineering Life Cycle and the Systems Engineering “Vee” ". Its objective is to provide summary information concerning systems engineering.

2.1.1 Relationship to Previous Chapter - This chapter transitions from the general introduction of a Concept of Operations for Regional Integration Projects in Chapter 1 to provide a brief introduction to systems engineering. This chapter is designed as a quick refresher for readers with a moderate amount of systems engineering experience to provide a foundation for the detailed guidance provided in later chapters. It also enables readers to determine the need to review the companion document or other listed references for more background information.

2.1.2 Chapter Sections:

- What Is Systems Engineering?
- Chapter Summary
- Specific Literature Supporting This Chapter

2.2 WHAT IS SYSTEMS ENGINEERING?

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Systems engineering was developed to address contemporary, large-scale, engineering projects involving large information technology components. Systems engineering facilitates the development, maintenance, refinement, and retirement, of dynamic, large-scale systems consisting of both technical components and human components. Systems engineering is an appropriate process for large-scale, technically sophisticated transportation projects. It is particularly important for a regional initiative where a structured process is essential to manage the large number of diverse operational elements and the often vast array of interconnects to satisfy a variety of users. The phases of the process are depicted in the widely used "Vee" graphic and briefly described below.

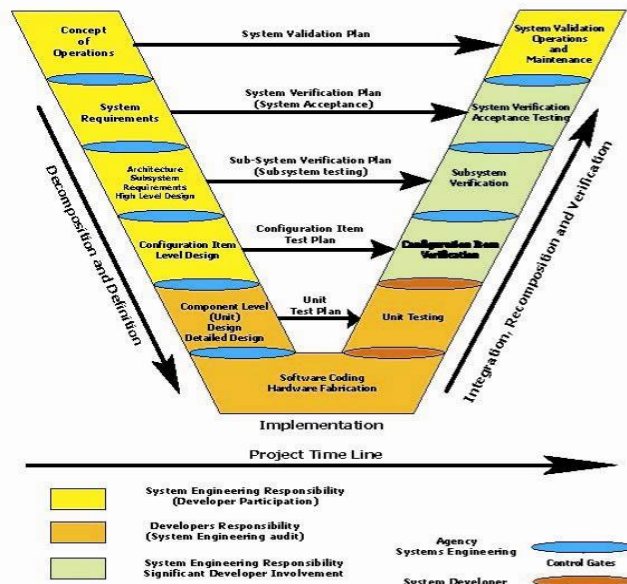


Figure 2.1 - The Systems Engineering "Vee" - Figure used in FHWA training courses- This model depicts the steps of the systems engineering process for the three methods:

Decomposition and definition (left line of vee): Concept of Operations, System Requirements, Architecture Subsystem Requirements/High Level Design, Configuration Item Level Design, and Component Level (Unit) Design/Detailed Design

Implementation (bottom of vee): Software Coding/Hardware Fabrication

Integration, Recomposition, and Verification (right line of vee): Unit Testing, Configuration Item Verification, Subsystem Verification, System Verification Acceptance Testing, and System Validation/Operations and Maintenance

Though the entire process is inherently iterative, the first and last step in this model includes the use of a Concept of Operations.

- Concept of Operations – The Concept of Operations is the first step in the systems engineering “Vee” – while integral throughout the entire process; its most critical, and directly related, roles will be in the direct assistance to the

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generation of System Requirements, and in System Validation once it has entered an Operations and Maintenance phase.

- System Requirements – The second step in the systems engineering “Vee” is the development of the overall System Requirements. The purpose of the requirements is to clearly define what the system will do.
- Architecture Subsystem Requirements/High Level Design – The third step is driven by the System Requirements. This step begins the process of organizing system functions into higher-level units. This is commonly referred to as system architecture.
- Configuration Item Level Design – This fourth step may be considered entering into the engineering design phase. At this stage, the process moves from a functional perspective of what the system will do, to a definition of how it will accomplish the functions.
- Component Level (Unit) Design/Detailed Design – This step involves the detailed design of all elements of the system. It is important to note that this is driven by all previous activities.
- Software Coding/Hardware Fabrication – With detailed input from the previous step, the actual build process begins here; software code is written, parts fabricated, and the system integrated.
- Unit Testing – At this stage, each subcomponent, or unit, which will exist within the greater system, is tested individually; they are verified by comparing with the component level design completed two steps earlier.
- Configuration Item Verification – After each subcomponent has been assembled, integration begins and appropriate configuration for each subcomponent must be performed. This step takes the components past the unit testing and begins to configure them for appropriate system operation. This configuration is tested by examining the original configuration item level design developed several steps earlier.
- Subsystem Verification – As subcomponents come together and are configured, they are tested to ensure proper operation.
- System Verification Acceptance Testing – This final testing step involves ensuring that all aspects perform as intended, and the system may be “accepted” for operation.
- System Validation/Operations and Maintenance – The last step, the system operates to fulfill its mission in the real world.

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It is important to mention that these steps are not terminal—an organization does not finish one step, and begin directly on the next step. The systems engineering process is only effective if viewed as iterative throughout each step of the process and also iterative in the long run. This dynamic process should take place over a period of years, not months or weeks.

Please consult the references listed below in Section 2.4 for more information about systems engineering.

2.3 CHAPTER SUMMARY

This chapter briefly summarized the phases of the systems engineering process, emphasizing the importance of the Concept of Operations to all phases of the process.

2.4 SPECIFIC LITERATURE SUPPORTING THIS CHAPTER

- Developing and Using a Concept of Operations in Transportation Management Systems; FHWA, Spring 2005

http://tmcps.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=38&new=0

- Gonzalez, Paul J. Building Quality Intelligent Transportation Systems Through Systems Engineering. Report No FHWA-OP-02-046. April 2002.

http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13620.html

- National Highway Institute Training. The National Highway Institute offers a wide-ranging selection of courses that relate directly to transportation operations. Their series on ITS includes the following courses directly addressing systems engineering (for additional information, please see the NHI web site, <http://www.nhi.fhwa.dot.gov>):
 - 137024A Introduction to Systems Engineering for Advanced Transportation
 - 137026A Managing High Technology Projects in Transportation